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SOILS REPORT

CINDER HILLS AREA

ELDEN RANGER DISTRICT

COCONINO NATIONAL FOREST

Survey and Report by:

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TABLE OF CONTENTS

		Page
Abstract		
Part I - Interpretations		
1.0	Survey Interpretations	4
1.10	Range Management (2200)	4
1.11	Column Headings for Table I	4
1.12	Soil-Range Environmental Group 1	5
1.13	Soil-Range Environmental Group 2	5
1.14	Soil-Range Environmental Group 3	6
1.15	Soil-Range Environmental Group 4	6
1.20	Recreation Management (2300)	6
1.21	Soil-Recreation Site Suitability Groups	9
1.22	Suitability Group I	9
1.23	Suitability Group II	9
1.24	Suitability Group III	10
1.25	Suitability Group IV	11
1.26	Suitability Group V	11
1.30	Timber Management (2400)	14
1.31	Timber Management Interpretations	14
1.32	Site Class II Timber Soils	15
1.33	Site Class III Timber Soils	15
1.40	Watershed Management (2500)	18
1.50	Wildlife Management (2600)	24
1.51	Wildlife Management Interpretations	24
1.52	Soil-Wildlife Environmental Groups	25
1.53	Soil-Wildlife Environmental Group 1	25
1.54	Soil-Wildlife Environmental Group 2	25
1.55	Soil-Wildlife Environmental Group 3	25
1.56	Soil-Wildlife Environmental Group 4	26
1.57	Soil-Wildlife Environmental Group 5	27
1.60	Soil Engineering (7100)	30
Part II - Soils and Related Information		
2.0	Introduction	34
2.1	Geology	34
	Map - Geology of the Cinder Hills	35
2.2	Geomorphology and Physiography	36
2.3	Climate	36
2.4	Vegetation	37
2.41	Pinyon-Juniper Association	37
2.42	Ponderosa Pine Association	37
2.5	Soils	38
2.51	Acreage and Proportionate Extent	38
2.52	Mapping Unit Characteristics	38
2.6	Photographs	51

LIST OF TABLES

Table No.		Page
1	Soil-Range Environmental Groups	7
2	Soil-Recreation Suitability Groups	12
3	Soil-Tree Growth Relationships and Factors Affecting Harvest	16
4	Watershed Management Interpretations	21
5	Soil-Wildlife Environmental Groups	28
6	Engineering Classification and Interpretation of Soils	31
7	Soil Profile Characteristics	40
8	Mapping Unit Acreage and Proportionate Extent	46
9	Mapping Unit Characteristics	47

ABSTRACT

The Cinder Hills Soil Survey comprises 78,128 acres. Eighteen soil series were identified and mapped. Twenty-one mapping units were described and mapped to include the eighteen series and three miscellaneous land types.

The soils were grouped into four soil-range environmental groups reflecting differences in productive potential, revegetative potential, and vegetative associations. Five recreation suitability groups were defined on the basis of slope, texture, coarse fragments, and depth. The best ponderosa pine producing soils are the Doney and O'Leary soils producing Site Class II timber. The soils range in hydrologic group from A to D. Due to cinder influence most soils in the area have moderately rapid to very rapid infiltration. Runoff is generally low in the Cinder Hills.

PART I - INTERPRETATIONS

1.0 Survey Interpretations

Interpretations for use in planning range, recreation, timber, watershed, wildlife, and engineering projects are emphasized in this section. These interpretations, with the soil map and information given in Part II of this report, can be used in detailed management planning.

1.10 Range Management (2200)

The soils of the Cinder Hills study area have been arranged into four Soil-Range Environmental Groups. Because range herbage production is directly related to soil physical properties, inherent fertility and climate, these factors have been used as the basis for establishing the Soil-Range Environmental Groups. Of the soil physical properties, plant available water holding capacity (Table 4, Column 7) is one of the most important and has been given emphasis.

The soils in the environmental groupings, their estimated herbage production potential, revegetation potential, adapted species, and vegetation association are given in Table 1. Estimated herbage production potential is listed in pounds per acre dry weight and was derived using ocular estimates combined with soil profile characteristics. Revegetation potential is based on surface coarse fragments, slope, and soil profile characteristics. Acreages and extents of the soils can be obtained from Table 7, Part II.

1.11 Column Headings for Table 1

The following discussion concerns Table 1 -- Soil-Range Environmental Groups.

Column (1) Soil-Range Environmental Group. These groupings are based on soil physical properties, inherent fertility and climate.

Column (2) Soil name and mapping unit number.

Column (3) Estimated herbage production potential (lb/A.). The following rating system is based on capacity to produce range herbage.

Herbage Production Potential	Pounds/Acre (Air-Dried)
High	2,000 +
Moderately High	1,000 - 2,000
Medium	500 - 1,000
Low	250 - 500
Very Low	50 - 250
Non-Range	< 50

Column (4) Revegetation Potential and Species Adapted. Revegetation potential relates to the anticipated success with present mechanical revegetation procedures. The following ratings are used.

High - The soils of this group provide favorable conditions for plant growth. No important limitations to mechanized equipment use exist.

Moderate - Limited restrictions exist for mechanized equipment use. There are limiting inherent soil factors that must be considered for successful revegetation.

Low - The soils of this group offer serious restrictions to mechanized equipment use. There may or may not be limiting inherent soil factors.

The adapted species for revegetation were selected using soil profile information, climate and moisture regime. Reference was made to FSH 2209.23, Nonstructural Range Improvements Handbook.

Column (5) Vegetation Association. The vegetation association describes the climax as dominant overstory vegetation of a site.

Column (6) Remarks. This column contains generalized descriptions of the soil components, slopes and landform.

1.12 Soil Range Environmental Group 1

This group consists of the nearly level Medicine, Deadman, Wupatki, and Hostettor soils. These are the best range forage producing soils in the Cinder Hills Area. They are mostly deep loam and clay loam soils developed from old alluvium on gently sloping terrain and have medium plant available water holding capacity. Most of the plant available moisture is depleted in May. Therefore this area is poorly suited for summer and fall grazing. They are grassland soils with open pinyon-juniper stands, with the exception of Hostettor, which is in the ponderosa pine zone. Since most of this area was closed to grazing, increased natural revegetation appears to be causing reduced vigor and dieback of mature pinyon and juniper trees. Adapted introduced species are weeping love grass and Turkestan bluestem. Side-oats grama, black grama, and blue grama are adapted native species. Surface runoff potential is generally slow with low surface and gully erosion hazard potential. However, some moderate gully erosion was noted on Medicine soils. Artificial revegetation is needed to stabilize these areas.

1.13 Soil-Range Environmental Group 2

Bandera, Sizer, and Freidlein soils comprise this environmental group. These soils are moderately deep and deep to underlying cinders or gravel and cobble and have developed on moderately sloping to moderately steep terrain. Bandera and Sizer soils are developed in cinder material and

Freidlein is developed in old alluvium from basalt and is fine textured. Plant available water holding capacity is low, and the moisture regime is favorable for summer grazing. Class III ponderosa pine canopy cover limits the amount of range herbage production. These soils are well adapted for pubescent wheat grass, hard fescue, and perennial rye. Surface runoff potential is medium to slow with low surface and gully erosion hazard potential.

1.14 Soil-Range Environmental Group 3

This group consists of the steep Moon and Bonito soils. Moon soil is developed from cinders on south-facing slopes of cinder cones. The vegetation association on Moon soil is pinyon-juniper. Bonito soil is developed from cinders on the north-facing slopes of cinder cones with a ponderosa pine vegetation association. A very low plant available water holding capacity is the primary limiting factor for range herbage production. A cinder cover of 0.5 to 12 inches on Bonito soils makes the moisture regime even more unfavorable for grasses. Moon soils have been heavily browsed by game, as a winter range, leaving the browse "hedged" and "high-lined." Adapted species are western wheat grass, hard fescue, side-oats grama, and cliffrose. Revegetation potential is moderate to low depending on thickness of the surface cinder layer. Seeding should be done from the air due to steep slopes. Surface runoff potential is medium to very slow and surface erosion hazard is low. Gully erosion hazard is moderate for Bonito and Moon soils.

1.15 Soil-Range Environmental Group 4

This environmental group is comprised of the Fremont, Strawberry, O'Leary, Robinson, Crater, Haywire, Cinderlake, Lava, and Doney soils along with the miscellaneous land types. Most of these soils are covered with at least 8-15 inches of cinders. In some cases, a soil has started to develop in the upper portions of the cinder layer. Crater and Haywire soils have no buried soil horizons within reach of plant roots but the cinder and ash material is fine textured enough to support some plants. Cinderlake soils and some of the miscellaneous land types have too thick a layer of coarse cinders for plants to become established. Some of the miscellaneous land types lack cinder layers on the surface, but the soils are shallow and very droughty. The soils in this group have mostly very low plant available moisture holding capacity, but some soils with moderate water holding capacity are limited by the thick surface layer of cinders. These soils and land types do not produce 50 lbs/acre useable forage and are considered non range. Grazing is highly detrimental to grasses growing on loose cinders.

1.20 Recreation Management (2300)

The soils in a recreation site are among the most important factors in determining the site's ability to support recreation development. Some important soil factors to be considered in planning recreational facilities

Table 1. SOIL-RANGE ENVIRONMENTAL GROUPS

Soil-Range Environmental Group (1)	Major Soils and Unit Number (2)	Estimated Herbage Production Potential Lb/A (3)	Revegetation Potential and Species Adapted (4)	Vegetation Association (5)	Remarks (6)
1	Medicine (60) Deadman (62) Wupatki (63) Hostettor (3)	1000-2000+	Moderate to High Weeping Love Western Wheat Hard Fescue Russian Wildrye Vine Mesquite Side-Oats Grama Yellow Sweet Clover Blue Grama Turkestan Blue Stem Black Grama	Pinyon-Juniper	Deep loam and clay loam soils developed from alluvium on gentle slopes. Medicine and Wupatki are loamy. Deadman i clayey. Hostettor is sandy. Hostettor soils are in the ponderosa pine forest.
2	Bandera (542) and Sizer Freidlein (50)	1000-2000	Moderate Pubescent Wheat Hard Fescue Perennial Rye Yellow Sweet Clover	Ponderosa Pine	Bandera and Sizer are developed from cinders on slopes of 5-40%. Freidlein is developed in alluvium and is fine textured.
3	Moon (573) Bonito (575)	250-1000	Moderate to Low Western Wheat Hard Fescue Russian Wildrye Side-Oats Grama (573) Yellow Sweet Clover Cliffrose	Pinyon-Juniper to Ponderosa Pine	Moon is developed from cinders on south-facing slopes of cinder cones. Vegetation association is P/J. Bonito is on north-facing slopes of cinder cones. Vegetation association is ponderosa pine.

Table 1. SOIL-RANGE ENVIRONMENTAL GROUPS (continued)

Soil-Range Environmental Group (1)	Major Soils and Unit Number (2)	Estimated Herbage Production Potential Lb/A (3)	Revegetation Potential and Species Adapted (4)	Vegetation Association (5)	Remarks (6)
4	Fremont (508) Strawberry (576) O'Leary (577) Robinson (578) Crater (580-581) Haywire (582) Cinderlake (584) Lava (587) Doney (588) Misc. (102-103-104)	< 50	Low Indian Ricegrass Sand Dropseed Side-Oats Grama Sand Bluestem Little Bluestem	Pinyon-Juniper to Ponderosa Pine	These soils are covered with at least 8-10 inches of raw cinders from recent volcanic activity. Crater is from sandy Aeolian material and sand-tolerant grasses may be seeded.

are aspect, topography, soil fertility, texture, permeability, depth, drainage and moisture relationships. The kind and density of vegetation, also an important factor, is largely determined by the kind of soil present.

1.21 Soil-Recreation Site Suitability Groups

The factors mentioned above were used in assigning the soils of the Cinder Hills Area to recreation suitability groups. Group I indicates the most favorable soil conditions and Group V indicates the poorest sites. Subgroups a, b, and c are designated primarily on the basis of slope, texture, and vegetation association.

1.22 Suitability Group I

The soils of this group are developed in deep, well-drained alluvium and are moderately to highly fertile. They are the best suited soils for recreation site development in the Cinder Hills Survey Area. Trafficability (compactibility) ranges from fair to excellent. Vegetative cover is good. Hostettor and Freidlein soils are in the ponderosa pine zone, and Medicine, Wupatki, and Deadman soils are in the pinyon-juniper zone. These soils are capable of maintaining a good vegetative cover with proper management.

Subgroup a

Hostettor (3), Medicine (60), and Wupatki (63) soils make up this subgroup. They are coarse to medium textured well-drained alluvial soils with a dense vegetative cover. Slopes are 0-15%. Few limitations exist for these soils.

Subgroup b

The soils of this subgroup are Freidlein (50) and Deadman (62). These well-drained alluvial soils have fine textured subsoils and support good vegetative cover. The clayey subsoils are poorly suited for filter fields, and if surface layers are removed from misuse trafficability will be impaired.

1.23 Suitability Group II

The soils in this group are medium and moderately fine textured, developed in cinders and have poor to good site productivity. All except Bandera and Sizer have a surface layer of cinders over buried soils. Trafficability ranges from poor to excellent. Vegetative cover is poor to good. All soils in this group are in the ponderosa pine zone except Strawberry (576) which is in the pinyon-juniper zone.

Subgroup a

The soils of this subgroup are O'Leary (577) and Doney (588). They are moderately fine textured, well-drained soils. Ground cover is sparse, but there is moderate canopy cover. Slopes are 0-40%, but most are less than 15%. Both soils have a series of

buried horizons covered by a layer of raw cinders 6-10 inches deep. Unpaved roads are usually graded down to the buried soil, thus creating a stable base. Windthrow hazard is moderate on O'Leary soils, but susceptibility increases with increased off-road vehicle activity. Vulnerable roots can be broken by vehicles running across them, thereby increasing blowdown potential. The existing Bonito Campground is on the O'Leary soils and similar sites can be constructed on these soils.

Subgroup b

Bandera and Sizer soils (542) make up this subgroup. These medium textured soils are developed in cinder deposits. They are well-drained with moderate vegetative cover. Slopes of 5-40% (ave. 15-20%) are the main limiting factors for recreation facilities in this subgroup. Site productivity is good.

Subgroup c

The Strawberry soils (unit 576) in this subgroup are very gravelly, well-drained, medium textured, and developed from air fall cinders, which includes a 5-15 inch surface layer in addition to a cindery substratum. A young, very weakly developed soil is forming in the surface cinder layer. This young surface soil is easily destroyed by off-road vehicle activity. Trafficability is good when the surface cinder layer is moist, but is fair to poor when dry. Slopes range from 10-40% and are one of the primary limitations for recreation site development. In addition, these soils are rated as fair for camp and picnic grounds and support sparse vegetative cover. This is the largest subgroup in the pinyon-juniper vegetation association.

1.24 Suitability Group III

The soils of this group are developed in recent airfall cinder and ash material and have poor to fair site productivity. Vegetative cover is poor. The shallow ponderosa pine roots in these soils are extremely vulnerable to breakage by off-road vehicles. This breakage is a direct cause of blowdown. The area comprising suitability Group III has considerable scenic value and much of it is adjacent to Sunset Crater National Monument. A large portion of Group III can be seen from the Cinder Hills Overlook.

Subgroup a

The soils in this subgroup are Crater (580) and Haywire (582). They are gravelly and very gravelly medium textured, weakly developed soils. Slope range is 0-40%, but most are less than 15%. They are excessively drained soils with poor vegetative cover. Most of the ponderosa pine is non-commercial (less than 20 cubic feet/acre/year growth), except for low Class III sites on some of the Crater soils. Furthermore, apical dominance is lacking and the trees assume many unusual forms that add to the aesthetic value of these soils. Apache-plume is the best suited understory species adapted to the Haywire soils. Trafficability is only fair during dry periods, but is good when the soils are moist.

However, these are young soils and off-road travel seriously retards soil development and causes undue damage to vegetation in these fragile conditions. This is the largest subgroup in the ponderosa pine vegetation association.

Subgroup b

Crater soil (Unit 581) is essentially like Unit 580 of subgroup "a" but is generally steeper (slope range 15-50%) and on north-facing slopes of recent cinder cones.

1.25 Suitability Group IV

The soils of this group developed in cinders on steep slopes of cinder cones. Recreation site suitability is, for this reason, limited.

Subgroup a

Moon soils (573) make up this subgroup. They are very gravelly, medium to moderately textured, well-drained soils on south slopes of cinder cones in the pinyon-juniper zone. Slopes are 20-60%. Runoff potential is medium and is due mainly to steep slopes and lack of vegetative cover. Gully erosion hazard potential is moderate and some gully erosion does exist. This is an important winter range area for deer.

Subgroup b

Bonito (575) and Robinson (578) soils make up this subgroup. These are very gravelly, medium to moderately fine textured soils on 20-65% slopes. Runoff is slow due to a 3-12 inch layer of raw cinders over the buried soil. The steep terrain severely limits recreational facilities and roads on these soils.

1.26 Suitability Group V

The soils and miscellaneous land types of this group are either too steep, rocky, or cindery to be adequate for recreation site development. However, they have unique characteristics associated with volcanic activity and have much scenic and recreational value.

Subgroup a

Cinderlake soil (584) and miscellaneous land type (102) make up this subgroup. The raw cinder layer over Cinderlake soil is greater than 15 inches in depth and too coarse and thick for significant plant establishment. Only a few pioneer species grow on these soils. Miscellaneous land type 102 is a cindery area with no vegetative cover. If any off-road vehicle use is desired in the Cinder Hills area, this sugbroup will suffer the least amount of damage.

Subgroup b

The soils in this subgroup are Lava (587) and Fremont (508) and Miscellaneous units 103 and 104. These units are extremely valuable scenic areas but generally are not suited for recreation site establishment due to very steep slopes, and poorly developed, erodible soils.

Table 2. SOIL-RECREATION SUITABILITY GROUPS

Suitability Subgroup (1)	Soils and Units (2)	Camp and Picnic Grounds (3)	Unsurfaced Roads (4)	Foot Traffic (5)	Vault Toilets (6)	Filter Fields (7)	Site Productivity (8)
I a	HOSTETTOR (3)	G	G-E (Moist) F (Dry)	G-E (Moist) F (Dry)	G	F-G	G
	MEDICINE (60)	E	E	G	E	G	E
	WUPATKI (63)	G	E	G	E	F	E
b	FREIDLEIN (50)	G	G	E-G	G-F	N.S.	G-E
	DEADMAN (62)	F	G	F	G	N.S.	G
II a	O'LEARY (577)	G	G	G	F	F	P
	DONEY (588)	G	E	G	G	E	F
b	BANDERA SIZER (542)	F-G	G	G	G	F-N.S.	G
c	STRAWBERRY (576)	F	G (Moist) P (Dry)	G (Moist) F (Dry)	F	N.S.	P
III a	CRATER (580)	G	G (Moist) F (Dry)	G (Moist) F (Dry)	P-F	P	F
	HAYWIRE (582)	F-G	G (Moist) P (Dry)	G (Moist) F (Dry)	F	G	P
b	CRATER (581)	P-N.S.	F (Moist) P (Dry)	G (Moist) P (Dry)	F-P	N.S.	P
IV a	MOON (573)	N.S.	P	F	F	N.S.	F
b	BONITO (575)	N.S.	P	P	P-F	N.S.	P
	ROBINSON (578)	N.S.	F	G (Moist) F (Dry)	F	N.S.	P
V a	CINDERLAKE (584)	F-P	G (Moist) P (Dry)	G (Moist) P (Dry)	F	F	P
	CINDERLAND (102)	N.S.	P	P	N.S.	N.S.	P

Table 2. SOIL-RECREATION SUITABILITY GROUPS (continued)

Suitability Subgroup (1)	Soils and Units (2)	Camp and Picnic Grounds (3)	Unsurfaced Roads (4)	Foot Traffic (5)	Vault Toilets (6)	Filter Fields (7)	Site Productivity (8)
b	ROCKLAND-UNDIFF. SOILS (103)	N.S.	P-F	P-G	N.S.	N.S.	P
	LAVA FLOW (104)	N.S.	F-P	G (Moist) P (Dry)	P-N.S.	N.S.	P
	FREMONT (508)	P-F	F-P	F-G	P	N.S.	F-P
	LAVA (587)	N.S.	F	G	N.S.	N.S.	P

1.30 Timber Management (2400)

The soils of the Cinder Hills Survey Area generally have a low potential for tree growth. Only 30 percent of the survey area contains commercial timber producing soils. Ten percent of the survey area is production Class II and 20 percent is Class III. The remaining 70 percent is non timber producing soils that are not listed in Table 3.

1.31 Timber Management Interpretations

The following discussion concerns Table 3 - Soil-Tree Growth Relationships and Factors Affecting Harvest.

Column (1) Soils and Mapping Unit Numbers

Column (2) Site Class. The following table gives the accepted R-3 production classes:

Region 3 - Site	Site Index	Production Class
High	75+	I
Medium	55-74	II
Low	54 and less	III

Nonsuitable (NS) indicates that timber species are not adaptable or they produce less than 20 cubic feet per acre per year. Site class data were obtained from standard R-3 site index curves for ponderosa pine.

Column (3) Regeneration Potential. This rating is indicative of the degree of limitation on regeneration of timber sites and is based upon percent survival among natural and planted seedlings.

% Survival	Regeneration Potential
75 - 100	High
50 - 75	Medium
0 - 50	Low

Column (4) Windthrow Hazard. Windthrow hazard ratings are based on factors that restrict normal root development thereby making a tree more susceptible to blowdown. Texture, cemented horizons and profile depth are considered factors.

Slight - Windthrow probability unlikely. Effective tree rooting depth is unrestricted.

Moderate - Windthrow probability is a management concern. Effective rooting depth is limited.

Severe - Windthrow probability is serious. Effective rooting depth is a serious limiting factor.

Column (5) - Equipment Limitation. This rating gives the degree of mechanized logging equipment limitation. The following rating system is used.

Slight - There is no special problem in the use of equipment.

Moderate -Conditions are becoming a limiting factor to logging equipment.

Severe Conditions present a serious limiting factor to logging equipment. The main factors affecting equipment use on timbered soils are slope, surface coarse fragments, erosion hazard, and erodibility.

Column (6) Remarks

1.32 Site Class II Timber Soils

There is no site Class I timber in the Cinder Hills Area. There are about 8,200 acres of site Class II timber on Hostettor (3), Freidlein (50), Bonito (575), O'Leary (577), and Doney (588) soils.

1.33 Site Class III Timber Soils

There are about 14,800 acres of site Class III timber producing soils on Fremont (508), Bandera and Sizer (542), Bonito (575), O'Leary (577), Robinson (578), Crater (580, 581), and Lava (587) soils. Of these 14,800 acres, approximately one third is either inaccessible or very low site Class III.

Soils and Unit Number (1)	Site Class PP (2)	Regeneration Potential (3)	Windthrow Hazard (4)	Equipment Limitation (5)	Remarks (6)
Hostettor (3)	II	Low	Slight	Slight	Site averages Class II, but ranges to Class III at lowest elevations. Soils are droughty. Low fertility.
Freidlein (50)	II	Med.-High	Slight	Slight-Mod.	Clay subsoils have low bearing strength when wet. Mod.-High grass competition. Mod. Fertility.
Fremont (508)	III	Low	Moderate	Severe	Steep slopes and stony soils. Low fertility.
Bandera and Sizer (542)	III	Low	Slight	Mod.-Severe	Calcareous in substratum. Severe grass competitio
Bonito (575)	30% II 70% III	Med.-High	Slight	Mod.-Severe	Steep north-facing slopes of cinder cones. There is a layer of raw cinders over a buried soil.
O'Leary (577)	60% III 40% II	Low	Moderate	Slight	The largest portion of this type is Class III. Soils are droughty due to a 5-15 inch layer of raw cinders over a buried soil. Light competition from woody shrubs (Apache-plume and big rabbitbrush).
Robinson (578)	III - N.S.	Low	Moderate	Severe	Steep slopes. These poorly developed soils are droughty due to a 5-15 inch layer of raw cinders over a buried soil. High competition from woody shrubs.
Crater (580)	III - N.S.	Low	Slight	Slight	These soils are from ashy Aeolian materials much of which is in the sand fraction. Soils are droughty with low fertility. 0-15% slopes.

Table 3. SOIL-TREE GROWTH RELATIONSHIPS AND FACTORS AFFECTING HARVEST (continued)

Soils and Unit Number (1)	Site Class PP (2)	Regeneration Potential (3)	Windthrow Hazard (4)	Equipment Limitation (5)	Remarks (6)
Crater (581)	III - N.S.	Low	Slight	Severe	These soils are similar to those above but are on steep north-facing slopes.
Haywire (582)	Not suitable	Low	Moderate	Slight to Moderate	Very gravelly cinder soils. Moderate equipment limitations are for dry conditions. Droughty with very low fertility. Trees on this site are twisted with little or no apical dominance.
Lava (587)	III - N.S.	Low	Slight	Severe	These soils are shallow and are associated with the lips of cinder cones. Very stony and droughty.
Doney (588)	II	Low	Slight	Slight	These soils have good moisture holding capacities in the buried soils. However, a 5-15 inch layer of raw cinders overlaying the buried soil causes a drought problem. 588 is the best timber soil in the cinder hills.
103	III - N.S.	Low	Slight	Severe	Steep rockland with shallow undifferentiated soils.
104	Not suitable	Low	Slight-Moderate	Severe	Broken lava flow rockland with pockets of cinders and rough basalt outcrops.

1.40 Watershed Management (2500)

Table 4 contains soil ratings and information significant to watershed management. Listed in the table are hydrologic soil groups, infiltration rate, permeability of least pervious layer, runoff potential, water storage values (field capacity and plant available water), and erosion hazard (sheet, gully, and current).

Column (1) Mapping unit name and symbol.

Column (2) Hydrologic Soil Groups. These groups are based on the intake of water at the end of long duration storms, after prior wetting and swelling. Slope and protection by vegetation are not considered.

There are four hydrologic soil groups:

Group A	Very low runoff potential
Group B	Low runoff potential
Group C	Moderate runoff potential
Group D	High runoff potential

These are subdivided on the basis of soil depth.

Soil Depth	Subgroup
Less than 20 inches	1
Greater than 20 inches	2
Misc. Materials	3

Column (3) Infiltration Capacity. Infiltration capacity is the ability of surface soil to sustain water intake. Soil characteristics of importance to infiltration capacity are surface soil texture, structure, organic matter content, porosity, and amount of surface coarse fragments.

Column (4) Permeability of Least Pervious Horizon. This refers to the readiness at which water moves through the soil profile. The amount of water percolating through a soil is determined by the permeability of the least pervious layer. Soil structure, texture, and pore space all influence permeability rates. Seven classes are used for rating permeability and infiltration:

Description	Rate
Very rapid	Over 20.0 inches/hour
Rapid	6.3 to 20.0 inches/hour
Moderately rapid	2.0 to 6.3 inches/hour
Moderate	.63 to 2.0 inches/hour
Moderately slow	.20 to .63 inches/hour
Slow	.06 to .20 inches/hour
Very slow	Less than .06 inches/hour

Column (5) Runoff Potential. This refers to the anticipated surface runoff potential based on hydrologic subgroup, ground cover, slope, and climate. Five classes are used for rating runoff potential.

Ponded	All precipitation enters the soil or is lost to evaporation. None escapes as runoff.
Very Slow	Surface water flows slowly over soil. Most of the water enters soil.
Slow	Surface water flows very slowly over soil. Large amounts of the water enter the soil.
Medium	Surface water flows at such a rate that a moderate portion of the water enters the soil.
Rapid	A large proportion of the precipitation moves rapidly over the surface of the soil and a small part moves through the profile.
Very Rapid	A very large part of the water moves rapidly over the surface and a very small part goes through the profile.

Column (6) Field Capacity (in.) Field capacity is the amount of water remaining in a well-drained soil when the downward movement of flow into unsaturated soil has become small or negligible. The estimated values for field capacity in this column depend on soil depth, texture, and coarse fragment content.

Column (7) Available Water Holding Capacity. Plant available water is the total moisture which may be taken from the soil by a plant. This implies that free drainage water has been removed and the moisture content is not below the wilting point. This estimated value as it appears in this column is a function of soil texture, depth, and coarse fragment content.

Column (8) Surface Erosion Hazard Potential. The potential net soil loss (in inches) and the erosion hazard rating are listed in this column. The potential net soil loss is an estimate of possible net soil loss assuming destruction of protective vegetation. It does take into consideration the protection given by surface coarse fragments.

The erosion hazard rating is a descriptive term correlated to potential net soil loss. The following separations are used:

Potential Net Soil Loss inches/year	Erosion Hazard Rating
0 - 0.25	Low
0.26 - 0.70	Moderate
0.71 - 1.00	High
1.00+	Extreme

Column (9) Gully Erosion Hazard Potential. This estimate of gully erosion hazard is based on conditions in the survey area and take into account the amount and intensities of rainfall. Ratings are:

High	Gully erosion is of extreme importance in planning. Soils are extremely susceptible.
Moderate	Gully erosion is of importance in planning. Soils are susceptible after misuse.
Low	Soils are susceptible only after prolonged misuse.

Column (10) Current Erosion. The present status of erosion condition is listed in this column.

Table 4. WATERSHED MANAGEMENT INTERPRETATIONS

Mapping Unit Name and Symbol (1)	Hydro Soil Group (2)	Infiltration (3)	Permeability (4)	Runoff Potential (5)	Field Capacity (6)	AWHC (in) (7)	Erosion Hazard Potential		
							Surface (8)	Gully (9)	Current (10)
Hostettor Gravelly Sandy Loam, 0-10% (3)	A_2	R	R	S	7.0	4.0	.005 L	M	Few Gullies Slight Sheet
Freidlein Gravelly Sandy Loam, 0-15% (50)	C_2	MR	S-MS	M	8.8	4.0	.04 L	L	Slight Sheet
Medicine Gravelly Loam, 0-15% (60)	C_2	MR	S-MS	M	12.3	6.8	.03 L	L	Few Gullies Slight Sheet
Deadman Very Gravelly Loam, 0-15% (62)	D_2	MR	VS	M	14.5	7.0	.07 L	L	Slight Sheet
Wupatki Gravelly and Very Gravelly Loam, 1-10% (63)	B_2	MR	MR	S	12.1	7.6	.03 L	L	Slight to Moderate Sheet
Fremont Gravelly and Stony Sandy Loam, 20-60% (508)	B_2	M-MR	M-MR	M-R	2.5	1.7	.40-.70 M-H	M	Few Gullies Moderate Sheet
Bandera and Sizer Gravelly Loam, 5-40% (542)	B	MS-MR	MS-MR	M-S	4.7	2.5	.05	L	No evidence of Erosion
Moon Very Gravelly and Gravelly Loam, 20-60% (573)	B_2	MR-VR	S-MR	M	4.3	2.6	.12 L	M	Few Gullies Moderate Rills Moderate Sheet

Table 4. WATERSHED MANAGEMENT INTERPRETATIONS (continued)

Mapping Unit Name and Symbol (1)	Hydro Soil Group (2)	Infiltration (3)	Permeability (4)	Runoff Potential (5)	Field Capacity (6)	AWHC (in) (7)	Erosion Hazard Potential		
							Surface (8)	Gully (9)	Current (10)
Bonito Gravelly and very Gravelly Loam, 20-50% (575)	B_2	VR	MR-MS	VS	3.6	2.4	.09 L	M	Light Sheet Common Rills and Small Gullies
Strawberry Very Gravelly Loam, 10-40% (576)	A_2	VR	VR	VS	1.9	1.2	.01 L	L	No Evidence of Erosion
O'Leary Gravelly and Very Gravelly Loam, 10-40% (577)	B_2	VR	MS	S	10.0	4.8	.01 L	L	No Evidence of erosion
Robinson Gravelly and Very Gravelly Loam, 40-65% (578)	B_2	VR	R	S-M	5.0	3.2	.05 L	M	Common Rill Erosion
Crater Fine Very Gravelly and Fine Gravelly Sandy Loam, 0-15% (580)	A_2	VR	VR	S-VS	1.8	1.0	.005 L	L	No Evidence of Erosion
Crater Fine Very Gravelly and Fine Gravelly Sandy Loam, 15-50% (581)	A_2	R	R	VS	2.2	1.7	.02 L	M	Common Rills and Small Gullies
Haywire Very Gravelly Loamy Sand, 0-40% (582)	A_2	MR	MR	VS	1.2	.7	.01 L	L	No Evidence of Erosion

Table 4. WATERSHED MANAGEMENT INTERPRETATIONS (continued)

Mapping Unit Name and Symbol (1)	Hydro Soil Group (2)	Infiltration (3)	Permeability (4)	Runoff Potential (5)	Field Capacity (6)	AWHC (in) (7)	Erosion Hazard Potential		
							Surface (8)	Gully (9)	Current (10)
Cinderlake Coarse Cinders 0-10% (584)	B_2	VR	MS	S	7.2	4.2	.02 L	L	No Evidence of Erosion
Lava Gravelly and Very Gravelly Loam, 10-60% (587)	B_1	MR	MR	S	1.6	1.0	.26 M	L	Light Sheet
Doney Gravelly and Very Gravelly Loam, 0-10% (588)	C_2	MR-VR	S	S	10.8	6.0	.01 L	L	No evidence of Erosion
Coarse Cinders, 20-60% (102)	A_2	VR	VR	VS					
Shallow, Cindery Soils Undifferentiated and Rhyolite, Andecite, and Dacite Outcrops, 20-80%	D_3	MS	MS	R					
Coarse to Fine Cinders Undifferentiated and Basalt Lava Flow, 5-40% (104)	D_2 D_3	R	S	S					

1.50 Wildlife Management (2600)

Deer and antelope are the principal big game animals of the Cinder Hills Area. In addition, some thirteen rodents and approximately the same number of birds have been observed.* In general, the Cinder Hills presently provide very little wildlife forage and habitat due mainly to the low frequency of palatable forbs and shrubs. The potential for improving wildlife habitat is high to low and can be facilitated with the introduction of a seed source for palatable herbage.

1.51 Wildlife Management Interpretations

The following discussion concerns Table 5 - Soil-Wildlife Environmental Groups.

Column (1) Soil-Wildlife Environmental Group. These soil mapping unit groupings are based on soil physical properties, inherent fertility (with emphasis on browse and forb production) and climate.

Column (2) Major Game Animals. The major game animals associated with an environmental group are listed. Information was obtained from the Arizona Game and Fish Department and from field observation.

Column (3) Major Soil and Unit Number

Columns (4) and (5) Adaptable Plant Species. Adaptable grasses are listed, but emphasis is placed on forb and browse species. Information was obtained from FSH 2209.23 - Range Improvement Handbook and field observation.

Column (6) Potential for Improving Habitat. This rating is an indication of the soil's ability to produce desirable wildlife feed. It is based on soil properties that determine the quantity and diversity of desirable species which can be produced. Three classes are used:

- High — There are no significant limitations for establishment of wildlife feed. Most of these areas probably supported better wildlife habitat in the past but have degenerated due to overuse.
- Moderate — Soil conditions are limiting so there is little possibility of establishing wildlife forage.
- Low — Conditions severely limit the feasibility of wildlife feed establishment. The area is not suited for production of significant quantities of wildlife forage species.

*Personal communication from Museum of Northern Arizona Staff and Arizona Game and Fish Department

1.52 Soil-Wildlife Environmental Groups

The soils of the Cinder Hills study area have been arranged into five Soil-Wildlife Environmental Groups based on soil physical properties, fertility and climate with emphasis placed on the ability of the soil to produce favorable wildlife habitat.

The soils in the environmental groupings, the major game animals, the adaptable plant species and habitat improvement potentials are listed in Table 5. Some soil characteristics are found in the Range Management Section.

1.53 Soil-Wildlife Environmental Group 1

This group consists of the nearly level Medicine, Deadman, Wupatki, and Hostettor soils developed from old alluvium. Antelope and deer are the major wildlife species. These soil types also provide an overwintering area for various types of song birds. The savannah-like nature of this area with scattered pinyon trees provides cover for the game species. The lack of palatable forbs and browse constitutes the main limiting factor for antelope and deer. Due to the low frequency of forbs and browse in the plant community a seed source must be provided. Habitat improvement potential is high. Adapted forbs are yellow sweet clover, woolly Indianwheat, buckwheat, and filaree. Adapted browse types are winter fat, fourwing saltbush, squawberry, and hackberry. Additional watering sites could be constructed in these soils.

1.54 Soil-Wildlife Environmental Group 2

This group consists of the Bandera, Sizer, and Freidlein soils. Bandera and Sizer soils are developed in old cinder deposits on gently rolling and hilly terrain. Freidlein is a fine-textured alluvial soil developed from basalt on undulating and gently sloping terrain. The most important wildlife species is deer. The soils of this environment group are timbered and provide good summer and fall habitat for deer. The forb and browse frequency and density, however, are somewhat depleted due to heavy use. Habitat improvement potential is high but natural regeneration must be supplemented by artificial seeding to provide increased quantities of feed. Adapted forbs are yellow sweet clover, alfalfa, burnett, and dandelion. Browse types are curl-leaf mountain mahogany, cliffrose, elderberry, and squawberry. The Freidlein soils are suited to construction of earthen watering sites.

1.55 Soil-Wildlife Environmental Group 3

The Moon, Robinson, and Lava soils developed from cinders on steep south-facing slopes constitute this group. These soils have been heavily used by deer as a winter range. In addition, several flocks of pinyon jays are centered in the Moon soil groups throughout the cinder hills and use juniper berries as their primary food source. The pinyon and juniper of

this environmental group provide good cover for deer. The browse, mainly cliffrose, has been hedged badly and is dying out of the plant community on Haywire Crater. Palatable forbs are at a very low frequency. Habitat improvement potential is moderate due to steep slope and soil loss by erosion. Adapted forbs are yellow sweet clover, buckwheat, and burnett. Adapted browse types are cliffrose, serviceberry, Apache-plume, and squawberry. This environmental group is poorly suited as a source of water for wildlife.

1.56 Soil-Wildlife Environmental Group 4

This group consists of the Crater, Haywire, Doney, O'Leary, Strawberry, and Fremont soils with miscellaneous land types 103 and 104. Crater, Haywire, Doney, Strawberry and O'Leary soils range from gently sloping to moderately steep and have a layer of raw cinders over a buried cindery soil. Fremont soil and miscellaneous land types 103 and 104 are steep and extremely steep, rocky and broken soils from basalt, rhyolite, andecite, and cinders. Deer are the major wildlife species present in this group. Approximately thirteen small mammals, two of which are game animals, are being effected by off-road vehicle activity on Crater and Haywire soils. These are:

Peromyscus boylei - Brush mouse
Peromyscus truei - Pinyon mouse
Peromyscus maniculatus - White-footed deer mouse
Reithrodontomys megalotis - Harvest mouse
Perognathus amphis - Arizona pocket mouse
Perognathus flavus - Silky pocket mouse
Perognathus Apache - Apache pocket mouse
Onychomys leucogaster - Grasshopper mouse
Citellus lecurus - White-tailed antelope ground squirrel
Citellus variegatus - Variegated rock squirrel
Sciurus aberti - Aberts squirrel (game species)
Neotoma sp - Wood rats
Sylvilagus anduboni - Cottontail (game species)

(Source - Museum of Northern Arizona Staff)

Off-road vehicles (dune buggies) often pass through fragile zones of vegetation on Crater and Haywire soils to reach the open cinder sidehills. In doing so, they cause severe disturbance of perennial plants supplying habitat for the above mentioned animal life.

Cover for deer generally is adequate in this environmental group. However, lack of forbs and browse constitutes the most important limiting factor. Clearing and planting of soils under the K.V. power line has resulted in considerable increases of grasses, forbs, and shrubs and a greater number of deer were observed near the powerline than in undisturbed areas on comparable soils. Small openings could be cleared and seeded elsewhere on Doney, Crater, and O'Leary soils to provide wildlife forage. Habitat improvement potential is moderate to low due to droughty condition of the cindery soils. Adapted forbs are buckwheat, flannel mullien, dandelion, and annual sunflower. Adapted browse

types are cliffrose, Apache-plume, and squawberry. The soils in this group are not suited for construction of earthen dams for additional water supplies.

1.57 Soil-Wildlife Environmental Group 5

This group contains Cinderlake soil and miscellaneous land type 102. They are on undulating to steep terrain and neither supports plant life due to deep, droughty cinders. There is no habitat improvement potential. Off-road vehicle damage to wildlife habitat is not a problem on this environment group.

Table 5 SOIL-WILDLIFE ENVIRONMENTAL GROUPS

Soil-Wildlife Environmental Group (1)	Major Game Animals (2)	Major Soil and (Unit No.) (3)	Adaptable Plant Species		Potential For Improving Habitat (6)
			Grasses and Forbs (4)	Browse (5)	
I	Antelope Deer	Medicine (60) Deadman (62) Wupatki (63) Hostettor (3)	Weeping Love Western Wheat Hard Fescue Russian Wildrye Vine Mesquite Side-Oats Grama Black Grama Blue Grama Turkestan Bluestem Yellow Sweet Clover Woolly Indianwheat Buckwheat Filaree	Winter Fat Fourwing Saltbush Squawberry (Skunk bush) Hackberry	High
II	Deer	Bandera and Sizer (542) Freidlein (50)	Pubescent Wheat Hard Fescue Perennial Rye Orchard Grass Yellow Sweet Clover Burnett Alfalfa Dandelion	Mountain-Mahogany Cliffrose Elderberry Squawberry (Skunk Bush)	High

Table 5 SOIL-WILDLIFE ENVIRONMENTAL GROUPS (continued)

Soil-Wildlife Environmental Group (1)	Major Game Animals (2)	Major Soil and (Unit No.) (3)	Adaptable Plant Species		Potential For Improving Habitat (6)
			Grasses and Forbs (4)	Browse (5)	
III	Deer	Moon (573) Robinson (578) Lava (587)	Western Wheat Hard Fescue Russian Wildrye Side-Oats Grama Yellow Sweet Clover Buckwheat Burnett	Cliffrose Serviceberry Apache-Plume Squawberry (Skunk Bush)	Moderate
IV	Deer	Crater (580-581) Haywire (582) Doney (588) O'Leary (577) Strawberry (576) Fremont (508) Misc. Land Type (103-104)	Indian Ricegrass Sand Dropseed Side-Oats Grama Sand Bluestem Little Bluestem Flannel Mullien Buckwheat Dandelion Annual Sunflower	Cliffrose Apache-Plume Squawberry (Skunk Bush)	Moderate to Low
V	----	Cinderlake (584) Misc. Land Type (102)	---------	--------	N.A.

1.60 Soil Engineering (7100)

The following discussion is related to Table 6 - Engineering Classification and Interpretations of Soils.

Column (1) Mapping Unit.

Column (2) Soil Name.

Column (3) Depth in Inches. This column gives thickness of the materials rated for engineering characteristics.

Column (4) U.S.D.A. Texture. This column gives the field textures such as loam, clay loam, clay, etc., and refers to the textural limits shown on the standard U.S.D.A. textural triangle.

Column (5) AASHO Classification. This column shows the American Association of Highway Officials classification system which is based on the field performance of soils.

Column (6) Unified Classification. The Unified System of soil classification, established by the U.S. Corps of Engineers, is based on the identification of soils according to their texture and plasticity and on their performance as engineering construction materials.

Column (7) Percent Coarse Fragments >2mm. This column shows the percent gravel in the profile.

Column (8) Percent Coarse Fragments >5 in. Rock Fragments larger than 5 inches in diameter do not fit into the engineering classification systems so they are listed separately in Column (8).

Column (9) Suitability for Unsurfaced Roads. The ratings in this column are the same as Column 4 of Table 2 -- Soil-Recreation Suitability Groups. The ratings give an indication of the limitations involved in unpaved road location.

The evaluation is based on the undisturbed soil profile after the removal of surface horizons.

Column (10) Cut Bank Stability. This column gives an indication of the degree of stability against slide failures on ten-foot cuts as steep as 3/4:1. Ratings of stable, moderately stable, and unsuitable are used. Consideration was given to erodibility of exposed materials, rock type, rock structure, soil textures, and grade of soil structure along with angle of of repose of materials.

Table 6. Engineering Classification and Interpretations of Soils

Mapping Unit (1)	Soil (2)	Depth in. (3)	Classification			Percent Coarse Fragments		Suitability for Unsurfaced (9) Roads	Cut Bank Stability (10)
			USDA (4)	AASHO (5)	Unified (6)	(7) >2mm	(8) >5 in.		
3	Hostettor	0-7	Sandy Loam	A-2-6	SC	20		Fair-Good	Unstable
		7-66+	Loamy Sand	A-2-4	SM	20			
50	Freidlein	0-3	Loam	A-4	ML	5	10	Good	Mod. Stable
		3-8	Sandy Loam	A-2-6	SC	15	30		
		8-32	Clay Loam and Clay	A-6/A-7-6	CL-CH	10	25		
		32-45	Stones, Cobbles, and Gravel	A-1-a	GP	25	60		
60	Medicine	0-5	Loam	A-4	ML	15		Excellent	Stable
		5-29	Clay Loam	A-6	CL	30			
		29-72	Sandy Loam	A-2-4-	SM	45	10		
62	Deadman	0-5	Loam	A-2-6	GC	65		Good	Stable
		5-31	Clay	A-7-6	CH				
		31-51	Sandy Loam	A-2-6	SC	10			
		51-55	Sandy Loam	A-2-7	SC	55	10		
63	Wupatki	0-9	Loam	A-2-6	GC	60		Excellent	Mod. Stable
		9-21	Sandy Loam	A-2-6	SC	15			
		21-60	Loamy Sand	A-2-4	SM	5			
508	Fremont	0-23	Sandy Loam	A-2-4	SM	30	25	Fair-Poor	Stable - Mod.-Stable
542	Bandera	0-18	Loam	A-4-6	ML	15	10	Fair-Good	Mod. Stable
		18-58	Cinders	A-1-a	GW	60	25		
573	Moon	0-2	Cinders	A-1-a	GW	100			
		2-14	Sandy Loam	A-2-6	SC	40	15	Poor	Unstable
		14-23	Loam	A-2-7	GC	85	5		
		23-37	Cinders	A-1-a	GW	100			

Table 6. Engineering Classification and Interpretations of Soils (continued)

Mapping Unit (1)	Soil (2)	Depth in. (3)	Classification			Percent Coarse Fragments		Suitability for Unsurfaced (9) Roads	Cut Bank Stability (10)
			USDA. (4)	AASHO (5)	Unified (6)	(7) >2mm	(8) >5 in.		
575	Bonito	0-6	Cinders	A-1-a	GW	80		Poor	Unstable
		6-13	Loam	A-2-6	GC	40	20		
		13-35+	Clay Loam	A-2-7	GC	40	25		
		35-51+	Cinders	A-1-a	GW	100			
576	Strawberry	0-60+	Loam	A-1-a	GW	80		Good (moist) Poor (dry)	Unstable
577	O'Leary	0-13	Cinders	A-1-a	GW	90		Good	Unstable
		13-35	Clay Loam	A-6	CL	35			
		35-52.	Loam	A-4	ML-CL	40			
		52-61+	Cinders	A-1-a	GW	100			
578	Robinson	0-4	Loam	A-2-6	GC	90	5	Fair	Unstable
		4-60+	Cinders	A-1-a	GW	75	5		
580-581	Crater	0-16	Sandy Loam	A-1-b	SW	15			
		16-60+	Cinders	A-1-a	GW	85	5	Fair	Unstable
582	Haywire	1-3	Loam	A-2-6	GC	30		Good (wet) Poor (dry)	Unstable
		3-6	Cinders	A-1-a	GW	100			
		6-9	Loam	A-2-6	GC	65	5		
		9-60+	Cinders	A-1-a	GW	100			
584	Cinderlake	0-17	Cinders	A-1-a	GW	90	10	Good (wet) Poor (dry)	Unstable
		17-28	Clay Loam	A-6	CL	15	5		
		28-34	Sandy Loam	A-2-6	SC	25	5		
		34-44	Cinders	A-1-a	GW	85	5		
		44-60+	Sandy Loam	A-2-6	SC	10	5		
587	Lava	0-5	Sandy Loam	A-2-6	SC	30	15	Fair	Mod. Stable
		5-20	Cinders	A-1-a	GP	40	40		

Table 6. Engineering Classification and Interpretations of Soils (continued)

Mapping Unit (1)	Soil (2)	Depth in. (3)	Classification			Percent Coarse Fragments		Suitability for Unsurfaced (9) Roads	Cut Bank Stability (10)
			USDA (4)	AASHO (5)	Unified (6)	(7) >2mm	(8) >5 in.		
588	Doney	0-12	Cinders	A-1-a	GW	100		Excellent	Mod. Stable
		12-29	Clay Loam	A-6	CL	10	5		
		29-34	Clay Loam	A-7-5	CL	25	5		
		34-50	Sandy Loam	A-2-6	SC	25			
		50-60+	Sand	A-1-6	SW	5			
102	Cinder Land	0-60+	Cinders	A-1-a	GW	90	10	Poor	Unstable
103	Rockland	Undifferentiated Soils						Poor	Unstable to Stable
104	Cinders and	Lava Flows						Fair	Unstable

PART II - SOILS AND RELATED INFORMATION

2.0 Introduction

This section of the report gives information about the soil series (Table 7) and mapping unit characteristics (Table 9). Only the Bandera and Sizer series are established series names. All other series described in the Cinder Hills have been assigned tentative names because they are new series not studied previously. These names are subject to change at some future correlation date. Tentative names have been assigned for ease in recognizing the various soils in the area.

General information on geology, physiography, and geomorphology, climate, and vegetation associations is presented in this section.

2.1 Geology

The Cinder Hills Area is a part of the San Francisco field, a major volcanic center on the southeast edge of the Colorado Plateau. The extrusive igneous rocks in the Cinder Hills Area are divided into three main groups. Robinson (1913) and Childs (1948).

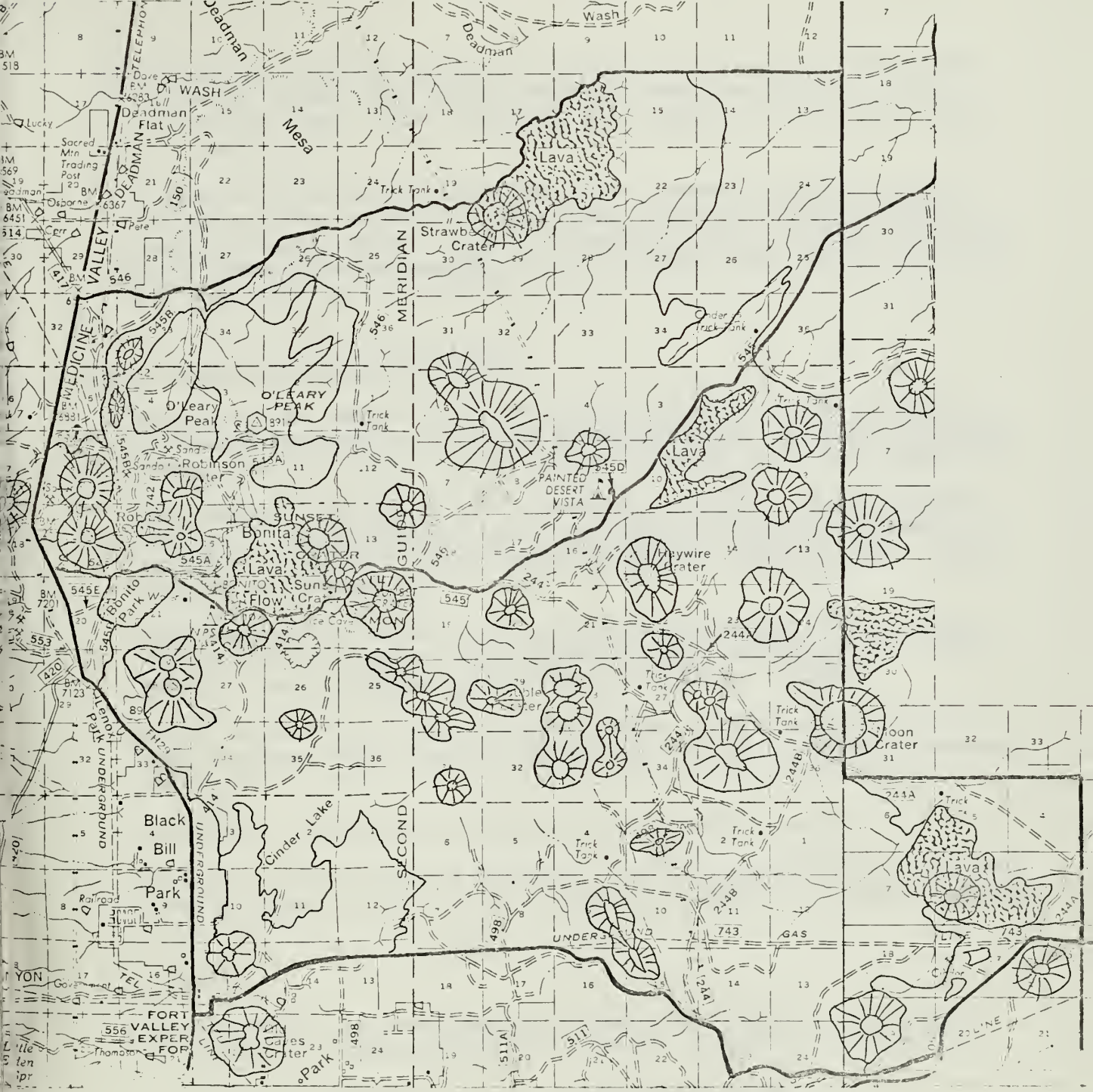
Stage	Description
I II	Basalt flows and cinders of the first, or oldest, eruption with acidic flows and associated pumice and tuff of the second period of eruption. Age ranges from late Pliocene to middle Pleistocene.
III IV	Basalt flows and cinders of the third, or youngest, period of eruption. Age range is from late Pleistocene to Recent.

The basalts of Stages I and II were extruded on erosion surfaces cut into Kaibab limestone and the Moenkopi formation. They are exposed along the edges of the volcanic field to the east of the Coconino National Forest.

The silicic volcanic rocks, principally andesite, rhyolite, and dacite, of the second eruption period are exposed on O'Leary Peak. These rocks are not fractured to an appreciable degree as are the basalts.

Basalt flows of Stages III and IV are widely exposed in the Cinder Hills near Sunset Crater, Strawberry Crater, and near the Leupp Road. They are distinguished from Stage I and II flows by their rough, fresh surfaces. These flows are made up of aa lava and are highly fractured.

Numerous cinder cones are present in the Cinder Hills Area, making it unique as one of the more recent volcanic fields of the continental United States. Cinder deposits form a layer over Stage III and IV lava flows as well as alluvial and glacial outwash areas. These cindery soils



GEOLOGY OF THE CINDER HILLS

- Alluvium
- Glacial Outwash
- Cinder Covered Glacial Outwash
- Lava Flows
- Cinder Covered (At least 6")
- Rhyolite, Andesite and Dacite

Cinder Cone

are the most extensive geologic type in the Cinder Hills. Small areas of glacial outwash from the San Francisco Peaks are located in Medicine Valley, Bonito Park, near Black Bill Park, and on the north flank of O'Leary Peak.

Several large old alluvial fans and stream channel deposits are near the edges of the Cinder Hills Study area located in Medicine Valley, Black Bill Park, the east side of Strawberry Crater, and near the Leupp Road. These deposits consist of layers of sand, silt, and cinders and may be as thick as seventy feet.

2.2 Geomorphology and Physiography

The survey area ranges in elevation from 5,300 feet in the northeast portion of the area to 8,913 feet on O'Leary Peak. Two prominant cinder cones, Sunset Crater and Double Crater, approach 8,000 feet in elevation.

The intercone basins have a mean elevation of 7,000 feet and contain shallow to deep cinder deposits. Topography consists of scattered cinder cones interspaced by ashy dunes and rounded, cindery hills. Runoff channels are non-existent.

Fans consisting of alluvial and glacial outwash deposits from the San Francisco Peaks protrude a short distance into the study area. Topography is gently sloping and dissected by drainage patterns.

Recent aa lava flows near Strawberry Crater, Sunset Crater, and the Leupp Road are rough, highly fractured, and scored by numerous fissures and cracks.

Topography is undulating and broken with no runoff channels.

Areas of alluvial soil are present on the eastern edge of the study area. These alluvial fans are gently sloping and dissected by shallow drainages.

2.3 Climate

The climate of the survey area is subhumid to semiarid. Mean monthly air temperatures are provided for Flagstaff at 7,006 feet elevation.

Month	Mean Monthly Air Temperature @ Flagstaff
January	27.6
February	30.8
March	36.2
April	43.1
May	50.3
June	59.2
July	65.6
August	63.8
September	57.4
October	46.8
November	37.2
December	29.6
Mean Ann.	45.6

Mean annual precipitation at Flagstaff is 19.7 inches. Precipitation generally occurs in the two-season pattern of the terminal fringe of the Monsoon belt, typified by frequent, moderate intensity winter storms and sudden, high intensity summer storms.

2.4 Vegetation

Three vegetative associations are described in the survey area, however, the lower mixed conifer zone is of little importance as it is confined to the top of O'Leary Peak. Vegetation for this association is not included in the report.

2.41 Pinyon-Juniper Association

This association extends from the lowest elevations of the survey area (5,300 feet) to 8,000 feet on the south-facing slopes of cinder cones. This association is characterized by deficient summer moisture.

Common Trees:	Pinyon Pine	Alligator juniper
	Utah juniper	
Common Shrubs:	Snakeweed	Douglas rabbitbrush
	Rubber rabbitbrush	Apache-plume
	Squawberry	Cliffrose
Common Forbs:	Locoweed	Buckwheat
Common Grasses	Blue grama	
	Black grama	Galleta

2.42 Ponderosa Pine Association

This is the dominant vegetation association in the Cinder Hills. Elevations range from 6,200 feet near the pinyon-juniper growth zone to 8,800 feet on O'Leary Peak. This association is characterized by deficient early summer moisture.

Common Trees:	Ponderosa pine	
Other Trees:	Douglas-fir	Limber pine
	Aspen	Utah juniper
	Pinyon pine	Alligator juniper
	Gambel Oak	
Common Shrubs:	Snakeweed	Squawberry
	Apache-plume	Cliffrose
	Rubber rabbitbrush	Chamiza
Common Forbs:	Rose pussytoes	Aster sp.
	Western yarrow	Flannel mullein
	Lupine sp.	

Common Grasses:	Arizona fescue	Pine dropseed
	Mountain muhly	Sand bluestem
	Squirreltail	

2.5 Soils

Twenty-one mapping units were identified and delineated. They represent 18 soil series and three miscellaneous units. Table 6 contains descriptions of representative profiles for each of the series. Following is an explanation of each of the columns.

Column (1) Map Symbol. These symbols follow a numerical system based on rock type.

Column (2) Series. Names are assigned to a collection of soil individuals essentially uniform in differentiating characteristics and in arrangement of horizons.

Column (3) Surface Soil. As used in this report surface soil refers to the A horizon. Thickness, color, texture, coarse fragments, and pH are described.

Column (4) Subsoil. In this report, subsoil refers to the B horizon. The characteristics given for Column (3) also are given here for subsoil.

Column (5) Substratum or Rock. Substratum refers to the C horizon.

Column (6) Tentative Classification. This column shows the placement of the series in the Comprehensive Soil Taxonomy System. The soils are classified down to the family level.

2.51 Acreage and Proportionate Extent

Table 8 lists the map units by name and symbol, acreage and proportionate extent of each in the survey area.

2.52 Mapping Unit Characteristics

Table 9 describes the important features of the mapping units. Following is an explanation of each of the columns.

Column (1) Map Symbol

Column (2) Name. This gives the mapping unit name.

Column (3) Elevation, Landform, Slopes. The elevation range, types of landforms and percent slopes are described.

Column (4) Mean Annual Precipitation (in/yr). These are estimated values extrapolated from local data and elevation - temperature curves.

Column (5) Vegetation. The dominant native species associated with the mapping units are listed.

Column (6) Soils and Geology. A description of ranges in characteristics of mapping units and surface geology is presented in this column.

Column (7) Significant Inclusions. Most mapping units contain small areas of soils differing from the dominant soils. These inclusions are described in this column.

Table 7. Soil Profile Characteristics

Map Symbol (1)	Series (2)	Surface Soil (3)	Subsoil (4)	Substratum or Rock (5)	Tentative Classification (6)
3	Hostettor	½-0", discontinuous pine litter layer, 0-6", dark gray, gravelly sandy loam, weak fine granular, 15% G, pH 7.2.	N.A.	6-66"+, light gray, gravelly loamy sand, single grain, 20% G, pH 7.2.	Mixed, frigid Typic Udipsamments
50	Freidlein	0-8", pinkish gray, gravelly sandy loam, moderate fine granular, 5-15% G, 5-10% K, 5-20% ST, pH 6.2.	8-15", pink, gravelly clay loam, weak fine subangular blocky, 10% G, 5% K, 20% ST, pH 6.6. 15-32", pink, gravelly clay, massive, 15% G, 5% K, 40% ST, pH 6.8.	32-45"+, pink, very gravelly clay, massive, 25% G, 10% K, 50% ST, pH 7.2.	Clayey skeletal Mixed, frigid Typic Argiborolls
60	Medicine	0-5", brown, gravelly loam, weak fine granular, 15% G, 5% K, pH 6.6.	5-29", light brown, gravelly clay loam, weak medium granular, 35% G, pH 7.2.	29-72"+, reddish yellow, very gravelly and gravelly sandy loam, massive, 30-45% G, 10% K, violently effervescent at 29-45", pH 8.0.	Coarse loamy, mixed Mesic Pachic Arguistolls
62	Deadman	0-5", pinkish gray, very gravelly loam, weak fine granular, 65% G, pH 7.6.	5-11", pinkish gray, clay loam, weak fine granular, 5% G. pH 8.0. 11-31", reddish yellow, clay, weak medium subangular blocky, 10% G, 2% ST, slightly effervescent at 31", pH 8.2.	31-55"+, pink, gravelly sandy loam, massive to single grain, 55% G. 10% ST, slightly effervescent from 31 to 55"+, 8.2.	Fine loamy, mixed Mesic Udic Haplustalfs

Table 7. Soil Profile Characteristics (continued)

Map Symbol (1)	Series (2)	Surface Soil (3)	Subsoil (4)	Substratum or Rock (5)	Tentative Classification (6)
63	Wupatki	½-0", layer of black cinders, 0-9", brown, gravelly to very gravelly loam, weak fine granular, 15%-60% G, pH 7.8.	N.A.	9-21", very pale brown, gravelly sandy loam, massive, 15% G, violently effervescent between 15 and 21", pH 7.6-7.8. 21-60"+, grayish brown, coarse sandy loam, massive to single grain, 5% G, violently effervescent 21-35", slightly effervescent 35-60", pH 8.0-8.2.	Coarse loamy, mixed, Mesic Typic Calciustolls
508	Fremont	½-0", discontinuous layer of pine and fir needles, 0-16", pinkish gray to brown, gravelly sandy loam, weak fine granular, 25% G, 20% K, 10-20% ST, pH 6.8-7.0.	N.A.	16-23", pinkish gray, very gravelly sandy loam, weak fine subangular blocky (rock controlled), 50% G, 15% K, 15% ST, pH 7.0. 23-26", over 90% fractured stone, rock, and gravel with some soil like above.	Loamy - skeletal over fragmental, mixed frigid, Typic Cryorthents
542	Bandera	0-7", brown, gravelly loam, weak fine granular, 25% G, pH 6.8. 7-12", brown, gravelly sandy loam, weak fine granular, 15% G, 2% K, pH 7.0.	N.A.	12-18", light brown, gravelly loam, massive, 30% G, 10% K, 5% ST, violently effervescent, pH 7.2. 18-31", light brown, gravel, layer of soil-coated cinders, 60% G, 20% K, 5% ST, slightly effervescent, pH 8.2. 31-58", black cinders, 90% G, 10% K, pH 7.5.	Cindery, Frigid, Entic Haploborolls

Table 7. Soil Profile Characteristics (continued)

Map Symbol (1)	Series (2)	Surface Soil (3)	Subsoil (4)	Substratum or Rock (5)	Tentative Classification (6)
573	Moon	2-0", layer of very dark grey cinders, 0-12", pale brown, very gravelly sandy loam, weak fine granular, 40% G, 10% K, 5% ST, pH 7.4-7.8.	N.A.	12-21", very pale brown, very gravelly loam, dom. by cinders, 85% G, 3% K, 2% ST, violently effervescent, pH 8.0. 21-35", black gravel (layer of raw cinders), single grain, 100% G, pH 8.2.	Cindery Mesic Typic Ustorthents
575	Bonito	1-0", layer of decomposing ponderosa pine needles	N.A.	0-6", black, very gravelly and (layer of raw cinders) 60% G, 5% K, pH 7.2	Cindery Frigid
		Buried Horizons - - -	- - - - - - - - - - - -	- - - - - - - - - - - -	
		6-13", light brown, very gravelly loam, weak fine granular, 40% G, 10% K, 10% ST, pH 6.8.	13-35", light brown, very gravelly clay loam, massive, 40% G, 10% K, 15% ST, pH 7.2-7.4.	35-51"+, black gravel (layer of raw cinders), single grain, 100% G, pH 7.6.	Typic Vitrandepts
576	Strawberry	0-3", brown, very gravelly sand, structureless, 80% G, pH 7.8.	N.A.	3-9", very dark gray, gravel (layer of raw cinders), 100% G, pH 8.0.	Cindery Mesic
		Buried Horizons - - -	- - - - - - - - - - - -	- - - - - - - - - - - -	
		9-26", pinkish gray, very gravelly loam, structureless 85% G, pH 8.0-8.2.	N.A.	26-32", light brown, very gravelly loam, structureless, 75% G, violently effervescent, pH 8.2. 32-42"+, very dark gray, gravel (raw cinders), single grain, 100% G, pH 8.2.	Typic Ustorthents

Table 7. Soil Profile Characteristics (continued)

Map Symbol (1)	Series (2)	Surface Soil (3)	Subsoil (4)	Substratum or Rock (5)	Tentative Classification (6)
577	O'Leary	0-6", very dark grayish brown, very gravelly sand, structureless, 80% G, pH 6.8.	N.A.	6-13", black gravel (layer of raw cinders), single grain, 95% G, pH 7.2.	
		Buried Horizons			
		13-23", light yellowish brown, gravelly clay loam, weak fine granular, 30% G, pH 6.6.	23-35", light yellowish brown, very gravelly clay loam, massive, 35% G, pH 7.4. 35-43", very pale brown, very gravelly loam, massive, 40% G, effervescent, pH 7.6.	43-52"+, very pale brown, very gravelly loam, single grain, 55% G, 5% K, violently effervescent, pH 8.0.	Cindery Frigid Typic Vitrandepts
578	Robinson	0-4", very dark grayish brown, very gravelly loam, single grain, 65% G, 5% K, pH 6.8.	N.A.	4-18", very dark gray gravel (layer of raw cinders), single grain, 100% G, pH 7.0.	
		Buried Horizons			
		N.A.	N.A.	18-60"+, pinkish gray, very gravelly loam, single grain, 75% G. violently effervescent between 36-60"+, pH 7.6-8.0.	Cindery Frigid Typic Udorthents
580-581	Crater	0-9", very dark grayish brown, very gravelly sand, single grain, 65% G, pH 7.0.	N.A.	9-25"+, very dark gray, fine gravelly sand, single grain, 65% G, 5% K, pH 7.4. 25-53", black gravel (cinders) Single grain, 100% G, Ph 7.8.	Cindery Frigid Typic Udorthents

Table 7. Soil Profile Characteristics (continued)

Map Symbol (1)	Series (2)	Surface Soil (3)	Subsoil (4)	Substratum or Rock (5)	Tentative Classification (6)
582	Haywire	0-1", decomposing ponderosa pine litter. 1-3", grayish brown, gravelly loam, structureless, 30% G, pH 7.0.	N.A.	3-6", dark gray gravel (raw cinders), single grain, 95% G, pH 7.8. 6-9", brown, very gravelly loam, structureless, 65% G, 10% K, pH 7.4. 9-85", black, very dark gray gravel (raw cinders), single grain, 100% G, pH 8.0.	Cindery Frigid Typic Ustorthent
		Buried Soil			
		N.A.	N.A.	85-95"+, brown, gravelly sandy loam, massive, 40% G, 5% K, pH 6.4.	
584	Cinderlake	N.A.	N.A.	0-17", black gravel (raw cinders), single grain, 90% G, 5% ST, 5% K, pH 8.0.	
		Buried Horizons			
		N.A.	17-28", light brownish gray, gravelly clay loam, weak fine granular, 25% G, 5% K, pH 7.0. 28-34", light brownish gray, gravelly sandy loam, weak fine granular, 25% G, 5% K, pH 7.0.	34-44", brown gravel (water laid cinders), single grain, 85% G, 5% K, effervescent, pH 8.2.	Cindery Frigid Typic Vitrandept
		Buried Horizons			
			44-92", light yellowish brown, sandy loam, massive, 10% G, 5% ST, pH 7.4.	92-117", light yellowish brown, gravel (cinder layer), massive, 80% G, 5% K, 5% ST, pH 7.4. Stratified cinder layers to basalt bedrock at 197".	

Table 7. Soil Profile Characteristics (continued)

Map Symbol (1)	Series (2)	Surface Soil (3)	Subsoil (4)	Substratum or Rock (5)	Tentative Classification (6)
587	Lava	0-5", pinkish gray, gravelly sandy loam, single grain, 30% G, 10% K, 5% ST, pH 6.8. 5-10", light brown, very gravelly sand, single grain, 40% G, 20% K, 20% ST, pH 7.0.	N.A.	10-20", pink, stones, gravel, and cobbles, structureless, 20% G, 30% K, 40% ST, pH 7.4. 20"+ red basalt flow rock	Sandy skeletal, mixed Frigid Lithic Ustorthent
588	Doney	1-0", decomposing ponderosa pine litter. 0-2", brown, very gravelly sandy loam, single grain (cinders), 60% G, pH 6.0	N.A.	2-8", brown, very gravelly loam (cinders), single grain, 85% G, pH 6.8.	Fine loamy, mixed Frigid Fluventic Eutrochrepts
		Buried Horizons			
		8-16", light brown, gravelly sandy loam, weak fine granular, 20% G, pH 6.8.	16-29", light brown, gravelly clay loam, weak fine granular, 15-25% G, effervescent to violently effervescent, pH 7.0.	29-68", light brown very gravelly sandy loam, massive, 60% GR, pH 7.8.	
102	----------Cinder Land ----------				Frigid to Mesic
103	----------Shallow cindery soils undifferentiated with Rhyolite, Andesite, and Dacite Rock Outcrops---				Frigid
104	----------Basalt Lava Flows ----------				Frigid to Mesic

Table 8. Mapping Unit Acreage and Proportionate Extent

Symbol	Mapping Unit Name and Slope Range	Acreage	Percent Extent
3	Hostettor gravelly sandy loam, 0-10%	656	.8
50	Freidlein gravelly sandy loam, 0-15%	400	.5
60	Medicine gravelly loam, 0-15%	3,312	4.2
62	Deadman very gravelly loam, 0-15%	560	.7
63	Wupatki gravelly and very gravelly loam, 0-10%	6,016	7.7
508	Fremont gravelly and stony sandy loam, 0-15%	400	.5
542	Bandera and Sizer gravelly loam, 5-40%	4,064	5.2
573	Moon very gravelly and gravelly loam, 20-60%	6,032	7.8
575	Bonito gravelly and very gravelly loam, 20-50%	2,096	2.7
576	Strawberry very gravelly loam, 10-40%	12,400	15.9
577	O'Leary gravelly and very gravelly loam, 10-40%	8,240	10.6
578	Robinson gravelly and very gravelly loam, 40-65%	496	.6
580	Crater fine very gravelly and fine gravelly sandy loam, 0-15%	2,496	3.2
581	Crater fine very gravelly and fine gravelly sandy loam, 15-50%	2,480	3.2
582	Haywire very gravelly loamy sand, 0-40%	11,152	14.3
584	Cinderlake coarse cinders, 0-10%	1,168	1.5
587	Lava gravelly and very gravelly loam, 10-60%	496	.6
588	Doney gravelly loam, 0-10%	2,848	3.7
102	Coarse cinders, 20-60%	7,328	9.4
103	Shallow, cindery soils undifferentiated and rhyolite, andesite, and dacite rock outcrops, 20-80%	1,504	1.9
104	Coarse to fine cinders undifferentiated and basalt lava flow, 5-40%	3,984	5.0
	Total	78,128	100.0

Table 9 Mapping Unit Characteristics

Map Symbol (1)	Name (2)	Elevations Landform Slope (3)	Mean Annual Precip. in/yr (4)	Vegetation (5)	Soils and Geology (6)	Significant Inclusions (7)
3	Hostettor Gravelly sandy loam	7,400 ft. Alluvial bottom 0-10%	20"	Ponderosa pine Sand bluestem Red threeawn Blue grama Arizona fescue	Coarse textured soils developed in deep alluvium from rhyolite, pumice, ash, andesite, and basalt	N.A.
50	Freidlein Gravelly sandy loam	6,750-6,850 ft. Dissected alluvial slope 0-15%	20"	Ponderosa pine Pine dropseed Blue grama Mountain muhly	Fine textured soils developed in alluvium from basalt. 0-20% stone - surface 20-50% stone - subsoil	N.A.
60	Medicine Gravelly loam	5,300-6850 ft. Alluvial slope 0-15%	17-18"	Blue grama with invading: Pinyon pine Utah juniper Snakeweed Rabbitbrush	Moderately fine textured calcareous soils developed in alluvium from basalt and cinders	10% of total area is Wupatki soil intermixed with Medicine soil
62	Deadman Very gravelly loam	5,500-6,300 ft. Alluvial slope 0-15%	14"	Blue grama Snakeweed Pinyon pine Utah juniper	Fine textured soils, calcareous in lower depths, developed in alluvium from basalt and cinders	12% of total area is O'Leary soil intermixed with Deadman soil. The O'Leary soils in this unit are confined to narrow drain bottoms.
63	Wupatki Gravelly and very gravelly loam	5,500-5,700 ft. Alluvial slope 0-10%	14-15"	Black grama Blue grama Red threeawn with invading: Pinyon pine Utah juniper	Moderately coarse textured calcareous soils developed in alluvium from cinders and outwash gravels	30% of area has a petrocalcic horizon (petrocalcic calliustoll as opposed to typic oali toll). Also about 20% of area has a thin layer ($\frac{1}{2}$-1") of cinders over Wupatki soil
508	Fremont Gravelly and stony sandy loam	8,400-8,700 ft. Steep mountain upland 20-60%	25-35"	Douglas-fir Limber pine Ponderosa pine Arizona fescue Mountain muhly Milkvetch spp.	Moderately coarse textured soils developed in colluvium from rhyolite, andesite, and pumice. 5-20% stone - surface soil 30% stone - substratum	5% of area is rock outcrop

Table 9. Mapping Unit Characteristics (continued)

Map Symbol (1)	Name (2)	Elevations Landform Slope (3)	Mean Annual Precip. in/yr (4)	Vegetation (5)	Soils and Geology (6)	Significant Inclusions (7)
542	Bandera and Sizer gravelly loam	6,500-6,750 ft. Low ridges and old cinder cones 5-40%	20"	Blue grama Squirreltail Snakeweed Ponderosa pine Pinyon pine Utah juniper	Medium textured gravelly, calcareous soils developed in old cinder deposits at the base of cinder cones. Sizer soils constitute 40% of the unit, Bandera soils 55%.	5% of mapping unit is an unnamed soil similar to Sizer developed in gravelly glacial outwash. Near Robinson Crater
573	Moon very gravelly and gravelly loam	5,500-7,000 ft. Cinder cone 20-60%	20"	Pinyon pine Utah juniper Apache-plume Cliffrose Annual forbs Blue grama	Medium textured very gravelly, calcareous soils developed in cinders on south-facing slopes of cinder cones. 0-10% stone - surface soil 0-5% stone - subsoil	5-10% of mapping unit is Bandera soil
575	Bonito gravelly and very gravelly loam	5,900-7,000 ft. Cinder cone 20-50%	20"	Ponderosa pine Arizona fescue Mountain muhly Sand bluestem	Moderately fine textured very gravelly soil developed in cinders on north-facing slopes of cinder cones. The buried, cindery soil is covered with 5-13" of raw cinders which is, in places, forming an A horizon	5% of mapping unit is an unnamed weakly developed soil with very gravelly sandy loam textures in the buried soil
576	Strawberry very gravelly loam	5,500-6,030 ft. Hilly 10-40%	14"	Pinyon pine Utah juniper Apache-plume Sand bluestem	Coarse textured soils, calcareous in lower depths, developed in airfall cinders. There are 5-15" of raw cinders over a buried A-C cinder soil	5% of mapping unit is basalt lava flow rock.
577	O'Leary gravelly and very gravelly loam	6,300-7,100 ft. Rolling intercone basins 10-40%	20"	Ponderosa pine Rabbitbrush Apache-plume	Coarse textured soils, calcareous in subsoil, developed in cinders. There are 9-13" of black coarse to fine cinders over a buried A-B-C soil. A weak A horizon is forming in the upper cinder layer	There are small inclusions of Bandera crater and Haywire soils within this mapping unit

Table 9. Mapping Unit Characteristics

Map Symbol (1)	Name (2)	Elevations Landform Slope (3)	Mean Annual Precip. in/yr (4)	Vegetation (5)	Soils and Geology (6)	Significant Inclusions (7)
578	Robinson gravelly and very gravelly loam	6,985-7,300 ft. Dissected, smooth mountain slopes 40-65%	21-22"	Ponderosa pine Apache-plume Annual forbs Blue grama	Very gravelly medium textured calcareous soils developed in airfall deposited cinders.	10% basalt, rhyolite, andesite, rock outcrops in unit
580	Crater fine very gravelly and fine gravelly sandy loam	6,800-7,150 ft. Rolling, intercone basins 0-15%	20"	Ponderosa pine Apache-plume Rabbitbrush	Coarse textured very gravelly soils developed in airfall fine and medium cinders and ash. Much of this soil is Aeolian ash	N.A.
581	Crater fine very gravelly and fine gravelly sandy loam	6,870-7,560 ft. Cinder cones 15-50%	20-21"	Ponderosa pine Rabbitbrush Apache-plume	Coarse textured very gravelly soils developed in airfall fine and medium cinders and ash. Much of this soil is Aeolian ash.	N.A.
582	Haywire very gravelly loamy sand	6,150-6,800 ft. Rolling intercone basins 0-40%	19-20"	Ponderosa pine Pinyon pine Apache-plume Annual forbs Sand bluestem Blue grama	Coarse textured very gravelly soil developed in airfall deposited coarse and medium cinders. This soil is much coarser than 580 and 581.	There are 15% inclusions of crater soils within the map unit.
584	Cinderlake coarse cinders	6,790 ft. Intercone basins 0-10%	20"	Annual forbs Ponderosa pine	15" depth of coarse airfall deposited cinders over a buried moderately fine textured soil.	N.A.
587	Lava gravelly and very gravelly loam	7,350-8,500 ft. Cinder cones 10-60%	20-22"	Ponderosa pine Pinyon pine Limber pine Alligator juniper Utah juniper Apache-plume Blue grama	Shallow, coarse textured very stony and cobbly soil developed on basalt flow rock on lips of cinder cones. 5-20% stone - surface soil 40% stone - substratum	Small pockets of sloping crater soils are present within this mapping unit

Table 9. Mapping Unit Characteristics (continued)

Map Symbol (1)	Name (2)	Elevations Landform Slope (3)	Mean Annual Precip. in/yr (4)	Vegetation (5)	Soils and Geology (6)	Significant Inclusions (7)
588	Doney gravelly loam	6,750-6,850 ft. Rolling intercone basins 0-10%	20"	Ponderosa pine Rabbitbrush Blue grama Sand bluestem Pine dropseed Annual forbs	Moderately fine textured calcareous soil formed in alluvial outwash with a 5-10" layer of recent cinders on the surface	Some inclusions of O'Leary and nearly level crater soils exist within this map unit
102	Coarse cinders	6,850-7,800 ft. Cinder cones 20-60%	20"	N.A.	Coarse airfall deposited cinder material	15% of map unit is made up of Crater and Haywire soils
103	Shallow, cindery soils undifferentiated and rhyolite, andesite, and dacite rock outcrops	7,800-8,916 ft. Steep mountain upland 20-80%	23-24"	Ponderosa pine Limber pine Pinyon pine Alligator juniper Douglas-fir Apache-plume Blue grama	Undifferentiated soils on steep, broken mountain faces with rock outcrops.	Very small inclusions of Fremont soil are present in the map unit
104	Coarse to fine cinders undifferentiated and basalt lava flow	5,800-6,810 ft. Lava Flow 5-40%	14-20"	Ponderosa pine Pinyon pine Alligator juniper Utah juniper Aspen Apache-plume Blue grama	Some Aeolean soils from fine cinders and ash in pockets of Lava flow	15% of map unit is made up of Strawberry soil and 15-20% is Crater and Haywire soils.

Figure 1. Level surface of Deadman soils (Unit 62) with O'Leary Peak in the distance (Unit 103). Trafficability is impaired on Deadman soils if the surface layer is removed by misuse.

Figure 2. Gently sloping surface of Wupatki soils (Unit 63) with the Cinder Hills in the distance. These are the best range forage soils of the study area.

Figure 3. Bandera soils (Unit 542) in foreground with juniper covered Moon soil (Unit 573) on south-facing slope and ponderosa covered Bonito soils (Unit 575) on north-facing slope of cinder cone.

Figure 4. Strawberry soils (Unit 576) in foreground with Moon soils (Unit 573) on cinder cone in distance.

Figure 5. Blowdown ponderosa pine showing root growth form on O'Leary soil (Unit 577).

Figure 6. Sloping surface of Robinson soil (Unit 578) with dense Apache-plume and sparse ponderosa pine. Rockland (Unit 103) in distance.

Figure 7. Example of an ecotone between Miscellaneous Land Type (Unit 102) in the foreground and Crater soil (Unit 580). The young, weakly developed Crater soils are slow to recover from logging damage and off-road vehicle use.

Figure 8. Example of stunted yellow pine on steep Crater soil (Unit 581). Regeneration is low on these sites.

Figure 9. Example of contorted ponderosa pine growth form on Haywire soil (Unit 582). Top of cinder cone in background shows flow rock (Unit 573) protruding through new Sunset Crater cinders.

Figure 10. More distorted ponderosa pine on Haywire soil (Unit 582). Many of these trees lack apical dominance.

Figure 11. Off-road vehicle use is detrimental to shallow ponderosa pine roots thereby causing increased windfall. Soil is Haywire (Unit 582).

Figure 12. Perennial grass plowed out by off-road vehicles. These zones of sparse vegetation on Unit 582 are important as areas of wildlife habitat.

Figure 13. Cinderlake soils (Unit 584) in foreground with Crater soils (Unit 580) to the right center of photo and Haywire soils (Unit 582) in the background.

Figure 14. Off-road vehicle damage on Haywire soil (Unit 582) with Lava soils (Unit 587) on the distant hilltops. The large exposure of cinders on the hillside is Miscellaneous Unit 102.

Figure 15. Level Doney soils (Unit 588) in the foreground. These are the best ponderosa pine producing soils in the Cinder Hills.

Figure 16. The aa lava flow in the foreground is Miscellaneous Land Type 104 with O'Leary Peak in the background (largely Miscellaneous Land Type 103).

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